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Vacuum Test of Cavity with Liquid Nitrogen

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Schematic of RAON vacuum system is introduced. Vacuum test for superconducting cavity with liquid nitrogen is performed. Schematic plan for RAON vacuum system is introduced and vacuum control system for superconducting cavity test is constructed. Vacuum pressure of cavity is shown as a function of pumping time. The temperature of cavity is shown as a function of cooling time. Outgassing species from cavity is also detected. Detailed experimental procedure is presented to test the cavity vacuum with liquid nitrogen.

Keywords : Cryogenic system, Vacuum system, Pump

I. Introduction

The RAON heavy-ion accelerator accelerates beam to 200 MeV/u. RAON consists of a low-energy superconducting linac (SCL1), a high-energy superconducting linac (SCL2) and a low-energy superconducting linac (SCL3). The SCL1 and SCL3 have the quarter-wave resonator (QWR) cryomodule and the half-wave resonator (HWR) cryomodule. SCL2 has the single spoke resonator (SSR) cryomodule. The QWR cryomodules can be operated with liquid helium of 4.3 K and other cryomodules can be operated with superfluid helium of 2.1 K. Superfluid properties of liquid helium are well-known and properties of superfluid fog were intensively investigated [1-3]. Molecular gas flow through a tube was investigated [4,5] and dynamic of capillary rise was studied [6]. Ultrahigh vacuum technology was developed for a large accelerator [7] and helium leak detection techniques were introduced for cryogenic system [8]. The effective temperature for non-uniform temperature distribution was studied [9,10].

In this research, we show the schematic of RAON vacuum system and software of vacuum control system for superconducting cavity test. Vacuum pressure and temperature of cavity are shown as a function of time.

II. Vacuum System

RAON consists of SCL1, SCL2 and SCL3. Fig. 1 shows the schematic of RAON vacuum system. RAON vacuum system consists of vacuum blocks, which have valve system, pump system, gauge system, and vacuum interlock. Each SCL can have many Programmable Logic Controller (PLC) and vacuum system. All PLC can be connected with PLC Network. Vacuum pressure can have 3×10^{-7} torr for ECR-IS (Electron cyclotron resonance ion source), 5×10^{-8} torr for low energy beam transport (LEBT), 5×10^{-8} torr for radio frequency quadrupole (RFQ), 5×10^{-8} torr for medium

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energy beam transport (MEBT), 1×10^{-9} torr for SCL1, 1×10^{-6} torr for charge stripper, 1×10^{-8} torr for SCL2, 1×10^{-8} torr for beam delivery, 1×10^{-6} torr for In-flight fragment (IF) target, 1×10^{-8} torr for pre-separator, 1×10^{-8} torr for matching section, and 1×10^{-8} torr for main separator.

Fig. 2 shows the software for vacuum control system. There are two control systems which consist of Experimental Physics and Industrial Control System (EPICS) and Programmable Logic Controller (PLC). PLC controls on and off of device powers and open and close of valves. MOXA computer gets vacuum pressure data from gauge controller and power controller of Turbo Molecular Pump (TMP) through RS232 protocol. EPICS softIOC runs on Linux operating system in MOXA computer. Operator Interface (OPI) is on the windows operating system. OPI is made of Control System Studio (CSS). PLC, MOXA computer and notebook computer are connected through Ethernet.

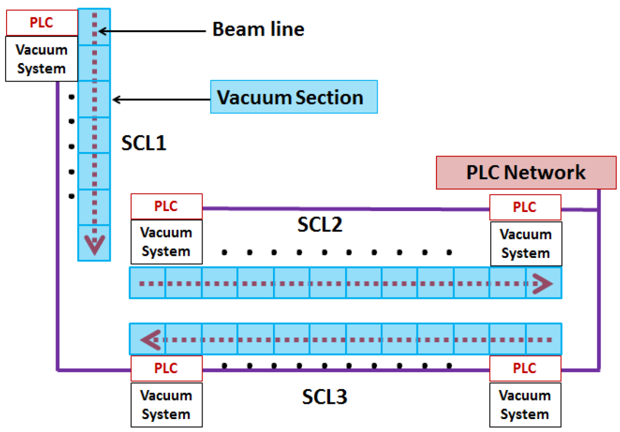

Figure 1. Schematic of RAON vacuum system.

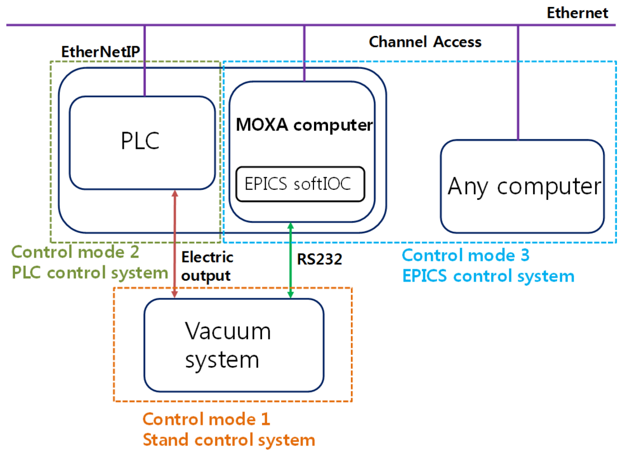

Figure 2. Software for vacuum control system.

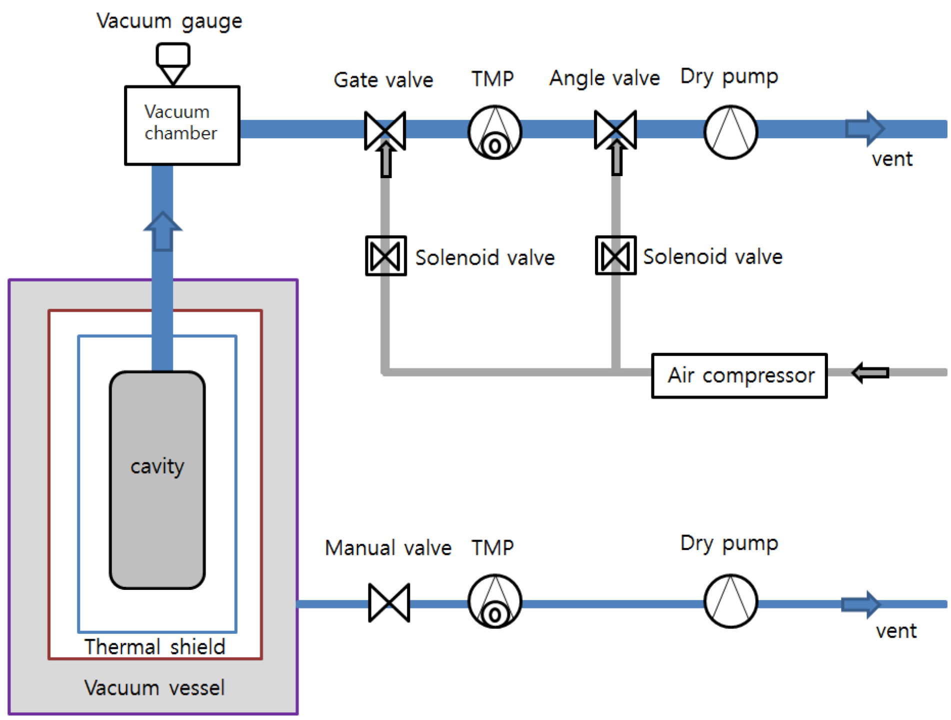

Figure 3. Vacuum control system for cavity test.

Fig. 3 shows the vacuum control system for vertical test. Vacuum control system consists of dry pump, TMP pump, valves, vacuum gauge, and vacuum interlock. Vacuum vessel can be evacuated by using TMP and dry pump for 5 hours. The pumping is stopped once the pressure is below 4×10^{-6} torr.

III. Experiment

Initially, the pressure of cavity is 1 bar, so the gate valve and angle valve are opened with solenoid valve. Dry pump is turned on and then turbo molecular pump (TMP) is turned on after the pressure of cavity is below 1×10^{-2} torr.

Fig. 4 shows the pressure of cavity as a function of pumping time. The pressure of cavity goes quickly down to order of 1×10^{-6} torr and slowly goes down after that. Liquid nitrogen is supplied 16 hours after pumping. The pressure decreases more rapidly after liquid nitrogen is supplied due to the cooling effect of the cavity.

Fig. 5 shows the temperature of cavity as a function of time. It took about 140 minutes to cool down the cavity with liquid nitrogen in the cryostat from room temperature to 77 K. The temperature of cavity decreases while liquid nitrogen is supplied and then the temperature keeps 77 K when liquid nitrogen covers the cavity.

Fig. 6 shows the pressure as a function of temperature. Pressure is increased with temperature. For perfect ideal gas law, the pressure increases linearly with temperature. It is expected that the pumping efficiency decreases as pressure decreases.

Residual gas analyzer (RGA) detects outgassing species from cavity. Fig. 7 shows the residual gas pressure of cavity from RGA data. Outgassing species consist mainly of H_2O, H_2, N_2, and CO_2.

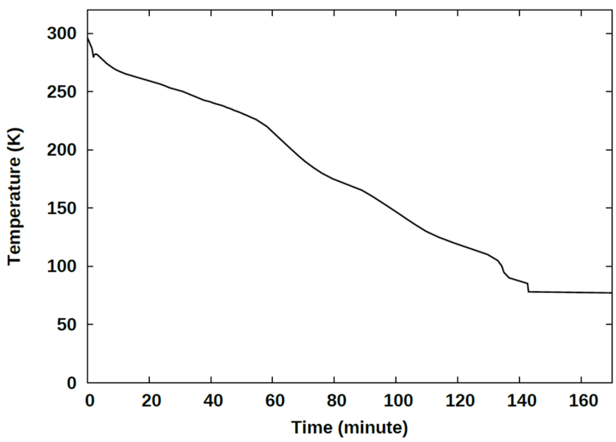

Figure 5. Temperature of cavity is shown as a function of time.

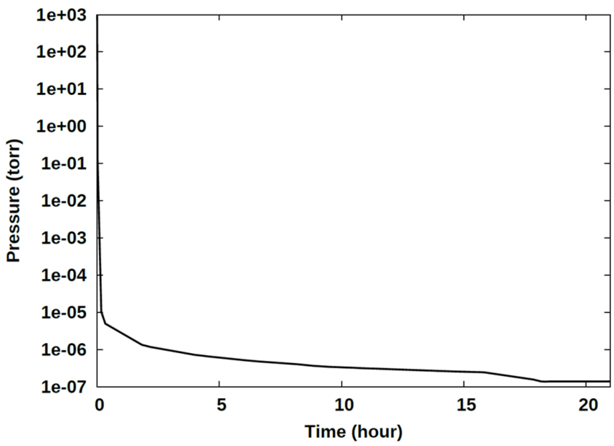

Figure 4. Pressure of cavity is shown as a function of time.

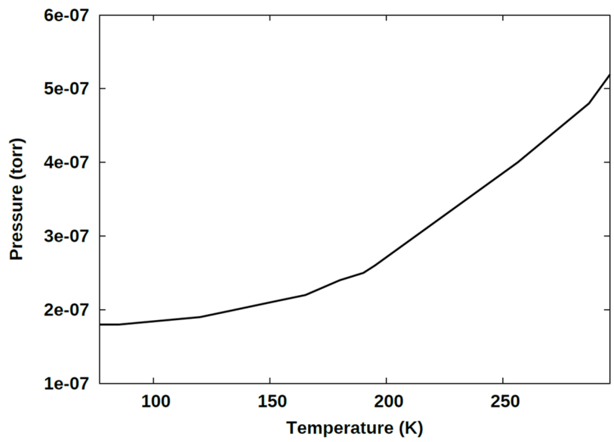

Figure 6. Pressure is shown as a function of temperature.

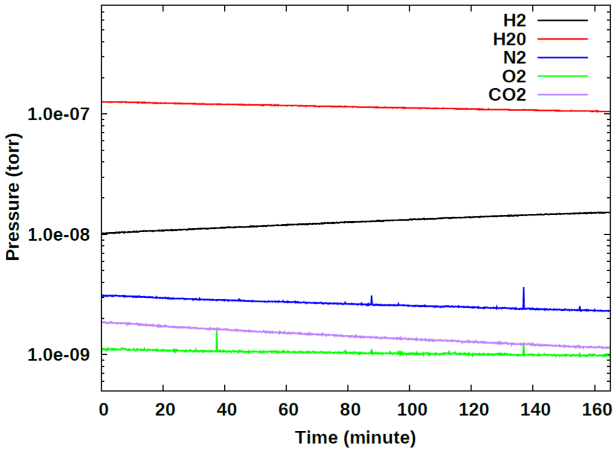

Figure 7. Residual gas pressure of cavity from RGA data.

IV. Conclusions

We have developed software for vacuum control system and measured pressure of cavity as a function of time and temperature. Vacuum control system for vertical test was shown. Pressure of cavity was shown as a function of pumping time. Temperature of cavity was measured as a function of cooling time. Pressure of cavity was expressed as a function of temperature. Residual gas was measured from the cavity.

Acknowledgements

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